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The Vestibulo-Ocular-Reflex Performance Evaluation Test (VORPET) developed at the Naval Aerospace Medical Research Laboratory gives a measure of left- and right-directed gaze shift threshold time used to assess the type of head/eye coordination relevant to the aviator who routinely makes large shifts in gaze during his scan of cockpit instruments and the outside environment. Automation of the VORPET requires the use of a voice recognition system for the collection and scoring of the subject's voice response. We tested the accuracy of the VOTAN voice recognition system in collecting subject's voice response to that of the present method that uses a test administrator to listen and hand enter subject's responses when administering the VORPET. Thirty-six subjects were administered the VORPET test under three different conditions (a) direct viewing of the stimulus digits presented on the CRT, involving no head movement, (b) VORPET administration using a test operator for subject's voice recognition and manual data entry, and (c) VORPET administration using the automatic voice recognition system for subject's voice acquisition and recognition. Four, three, and two digits were used as visual stimulus for each method used. The hypothesis to be tested was that there would not be a significant statistical difference in the results when methods (b) and (c) were used. Analysis of variance of test results indicate that there were significant differences between the thresholds obtained when method (b) and (c) were used to administer the VORPET. The VOTAN automated voice recognition system cannot be used to automate the VORPET. Present speed and accuracy of automated voice recognition systems still need additional technological advancement or improvement in order to replace the present "human based voice recognition system."

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FOREWORD

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Efrain A. Molina 1/15/1992

Principal Investigator's Signature Date

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1. INTRODUCTION

This Final Report covers work done at the Naval Aerospace Medical Research Laboratory during fiscal years 1990 and 1991. The Joint Working Group on Drug Dependent Degradation in Military Performance (JWGD MILPERF) was established for the purpose of developing and testing procedures to evaluate the effects of chemical defense pharmaceutical agents on military performance. The JWGD MILPERF has sponsored the performance assessment research effort at the Naval Aerospace Medical Research Laboratory (NAMRL) that has evolved from independent contributions by various scientific disciplines into an organized multidisciplinary test system called the NAMRL Multidisciplinary Performance Test Battery (NMPTB). The NMPTB has been designed for assessing aviator performance from a five-discipline perspective (i.e., cognitive, vestibular, visual, auditory, and physiological). Other products of sponsored research efforts from NAMRL are computational models of human performance in operational tasks and in laboratory performance tests.

The Vestibulo-Ocular-Reflex Performance Evaluation Test (VORPET) is one of the major component tests in the NMPTB. It allows assessment of the type of head/eye coordination that is required in a variety of military weapons systems (especially aircraft). It is most relevant to the aviator who must make large shifts in gaze during his scan of cockpit instruments and scenes in the outside environment such as horizon, targets, and wingman position when doing formation flying. In a JWGD MILPERF sponsored validation study, the VORPET results indicated degradation of performance as a result of antihistamine administrations, indicating that the VORPET may be useful as a sensitive NMPTB performance test.

The test requires the subject to directly face one display that provides visual fixation, and upon presentation of a simultaneous visual and auditory cue, to rapidly rotate his head toward the second display. At the onset of the cue, four digits are presented for a brief exposure time on the second display; the subject task is to call out as many as possible of the four digits that he can correctly identify (presently, the subject response is manually entered into the computer's keyboard by the operator). The exposure time of the second display is appropriately adjusted (increased or decreased) according to the accuracy of response of the previous trial. The procedure is repeated for a number of trials with the role of the first and second displays sequentially interchanged resulting in bidirectional gaze shifts. The end result is a single threshold time for each direction of gaze shift, and a grand mean threshold time based on the simple mean of the left- and right-directed gaze shift thresholds.

The main objectives of this research effort for the years FY90 and FY91 were:

(a) To complete and refine the automation of test instructions and computerized scoring of the VORPET test using voice-actuated subject response and test instructions.

(b) To construct two to four (depending on cost, space, and acoustical isolation requirements) automated VORPET test stations and install them in NAMRL's Mobile Field Laboratory trailer #5 after appropriate modification of the trailer required for additional test stations.

(c) To conduct baseline validation studies such as test/retest reliability studies.

(d) Perform systematic follow-on studies to incorporate appropriate additional tests derived from the NAMRL Multi-disciplinary Performance Test Battery, which has been developed for assessing performance effects of chemical defense antidote/pretreatment drugs.

In order to accomplish objective (a), the VORPET(1) test initially designed and implemented to operate in the BASIC language running on a Hewlett-Packard based digital computer was upgraded to operate in a Zenith Z-248 environment, and adapted to use a voice-recognition interface in order to automate test administration. The automated VORPET was then compared to the manual VORPET method of data entry by the test operator.

Statistical analysis of the data collected from both methods and a third static VORPET test indicate that the automated VORPET test does not yield the same threshold measurements and that it will introduce unknown effects.

State-of-the art technol[illegible] in voice recognition needs further improvement. Higher data acquisition sampling rate and more efficient algorithms are needed in order to provide the accuracy required. The use of IBM, and IBM compatible computers like the 386 and 486 systems with a much higher rate of instruction execution (33 MHz) in combination with faster Digital Signal Processors (DSP) to acquire and analyze human voice responses (50 MHz), and more efficient algorithms should make acquisition and analysis of rapid voice responses more accurate.

The other listed milestones were not completed. Further work needs to be done in the area of digital signal processing. There is a need for the use of voice recognition systems in computer-based testing similar to the one needed to incorporate the VORPET test as part of the NMPTB.

2. METHODS

The VORPET initially designed and implemented to operate in the BASIC language running on a Hewlett-Packard based digital computer was upgraded to operate in a Zenith Z-248 environment. The VORPET software programs were converted from the BASIC language to the C language and transported to run in Z-248 based IBM AT compatible computer. The programs were modified to incorporate the VOTAN automatic voice-recognition system in order to automate test administration.

Implementation of the software program for administration of the VORPET was done in the C language for two main reasons: (a) code compactness, and (b) all the library routines to interface to the VOTAN voice-recognition interface are available only for the C language.

Next, the accuracy of the new automated VORPET test was compared to that of the manually administered version. An experimental test design was prepared to measure the left- and right-directed gaze shift threshold times (in milliseconds) under three different test conditions:

Method 1. VORPET test administration with the subject directly viewing the stimuli digits displayed on a CRT, with no head/eye motion required, and using only the voice recognition system to collect the subject's responses. This method was considered to be a static VORPET test, to give a measure of accuracy of the voice recognition interface system.

Method 2. VORPET test administration using the manual method where the subject's voice response collected by the test operator is used to determine the thresholds.

Method 3. VORPET test administration using the VOTAN voice recognition system to collect and evaluate the subject's voice responses to determine the thresholds.

The VORPET under the three different test conditions was administered using two, three, and four stimuli digits. Both the operator's manually entered response and the responses collected by the voice-recognition system were recorded in methods 2 and 3. Thirty-six naval aviator students waiting for flight training from the Naval Aviation School's Command participated in the experiment.

Figure 1 shows the flow-chart diagram of how the VORPET test was administered. The test was configured in this manner to facilitate execution of the experimental design described below.

Test Administration. As soon as hardware and software initialization is completed, prerecorded voice instructions are

given to the subject by the VOTAN voice-recognition system (the voice recognition system can be programmed to provide voice instructions or messages) about the test to be administered. Next, subject and test-related information are entered by the test operator.

Prior to its use to capture and to record the subject's voice responses, the VOTAN voice-recognition system is trained to the subject's vocal responses (the numbers 2 through 9 in the case of the VORPET test) that are used throughout testing. Instructions are given to the subject about the training period.

At the end of VOTAN's voice-recognition training, a test or evaluation of the training is performed. Instructions are given to the subject about the evaluation. At the end of the training test, a summary of percentage accuracy for individual numbers 2 through 9 as well as in groups of four numbers presented in random order is displayed on the CRT screen for the operator to see. Results are also printed and stored on magnetic media.

The operator is then queried by the program about the need of repeating the training/evaluation. If the operator responds affirmative, training/evaluation is repeated, otherwise the VORPET test is then administered.

There were three methods of VORPET test administration:

1 - No Head Movement Mode. In this mode, the stimuli numbers are displayed on the CRT screen, which the subject views with no gaze shifts required. In this mode, the voice-recognition system is used to record the responses and to interpret the results, which are used to determine the gaze thresholds (VORPET thresholds).

2 - Manual Data Entry Mode. In this mode, the stimuli numbers are presented in the standard fashion that the VORPET test is administered. Both voice-recognition system and manual data entry by the operator are used to record the subject's responses. However, only the manual data entered by the operator are used to determine the VORPET thresholds.

3 - Voice Recognition Mode. In this mode, the stimuli numbers are presented in the standard fashion that the VORPET test is administered. Both voice-recognition system and manual data entry by the operator are used to record the subject's responses. However, only the responses collected by the voice recognition system are used to determine the VORPET thresholds.

The final form of the VORPET will be the same as that shown by the flow-chart in Figure 1, with decision making for retraining of the voice-recognition system to be computer automated.

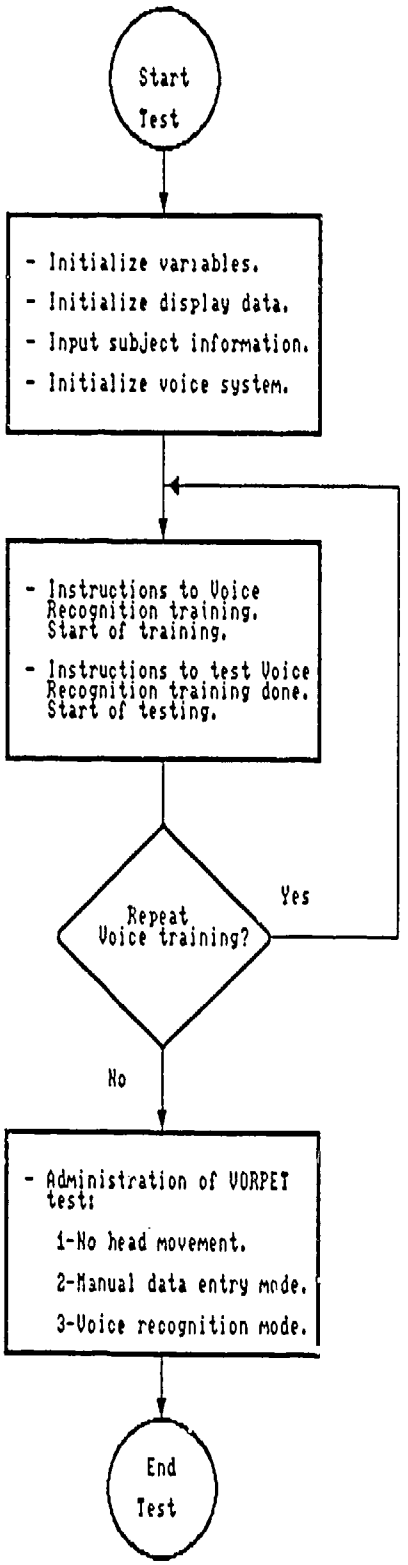


Figure 1. VORPET Flow-Chart Diagram.

Experimental Design. Thirty-six subjects were administered the VORPET under each of the test modes described above and for four, three, and two stimuli digits. The sequence in which the three different modes were administered was randomized but balanced. The 36 subjects were split into 3 different groups. Seven subjects had missing test data.

Hypothesis. The main hypothesis to be tested is that the mean of gaze thresholds for methods two and three are the same:

H_o: $\mu_1 = \mu_2$ The mean of the gaze thresholds are the same.

H_1: $\mu_1 \neq \mu_2$ The mean of the gaze thresholds are different.

and that the introduction of the automated voice-recognition system does not alter the measurements of both right- and left-gaze thresholds.

Each subject was given a total of 32 trials each time the VORPET was administered, with a 30-s rest interval at the end of the 16th trial.

Tables I, II, and III illustrate the right-gaze threshold means, the left-gaze threshold means, and the grand-gaze threshold means (left and right threshold average), respectively, for each of the 36 subjects tested using methods 1, 2, and 3 described above, when 4, 3, and 2 digits were used as the stimuli.

3. RESULTS AND DISCUSSION

The VORPET provides a measure of the right- and left-gaze threshold as well as the "grand mean threshold" defined to be the average of both the right- and left-threshold every time a subject is tested.

The data tabulated in Tables I, II, and III were analyzed with the aid of the SuperANOVA(2) Statistical Package run on a Macintosh digital computer. Analysis results include Anova Type III Summary Table, Modeling, Interaction Plots, and a Type III Manova table of the following:

(a) the variables Four-Digits, Three-Digits, and Two-Digits as a function of the methods used, namely, Method-1, Method-2, and Method-3.

(b) the variables Method-1, Method-2, and Method-3 as a function of the number of digits used as stimuli, namely, Four-Digits, Three-Digits, and Two-Digits.

Table I - Mean right-gaze thresholds

FINAL THRESHOLD-RIGHT
milliseconds

Obs.	Four-Digits			Three-Digits			Two-Digits		
	Method			Method			Method		
	1	2	3	1	2	3	1	2	3
001	573	516	546	545	460	999	.	.	.
002	545	778	641	487	487	541	.	.	.
003	487	641	545	.	.	.	.	.	.
004	659	705	712	.	.	.	.	.	.
005	487	705	705	487	516	573	460	487	487
006	605	516	641	487	487	514	460	460	575
007	460	705	853	545	487	631	460	487	487
008	460	541	487	460	460	516	460	460	460
009	487	623	573	460	460	487	460	460	460
010	545	596	750	514	460	641	575	487	516
011	487	487	487	545	487	487	.	.	.
012	460	623	742	460	460	487	460	487	460
013	577	577	659	487	460	609	674	487	631
014	514	516	609	487	460	516	487	460	460
015	577	676	666	545	460	545	460	487	487
016	487	605	609	.	487	596	487	460	545
017	460	487	487	460	460	460	487	460	487
018	460	573	575	514	596	750	487	460	637
019	487	705	631	460	545	516	460	487	487
020	545	744	825	516	541	577	487	460	596
021	783	545	545	545	487	545	487	487	609
022	516	607	668	460	487	487	487	487	516
023	514	541	643	666	487	666	487	460	545
024	545	744	712	487	545	514	487	487	573
025	487	744	705	460	573	631	487	514	460
026	750	596	712	516	573	641	575	460	516
027	516	516	545	545	460	516	460	460	573
028	641	516	674	631	487	605	460	460	460
029	513	631	659	460	487	577	545	487	514
030	487	516	514	460	460	487	487	460	487
031	577	545	750	577	514	516	546	487	487
032	488	573	705	516	577	666	487	596	545
033	545	545	577	460	514	545	460	460	545
034	596	862	712	487	596	541	545	487	487
035	487	674	668	487	460	577	516	460	487
036	.	596	605	825	487	516	577	460	575

Table II - Mean left-gaze thresholds

FINAL THRESHOLD-LEFT
milliseconds

Obs.	Four-Digits			Three-Digits			Two-Digits		
	Method			Method			Method		
	1	2	3	1	2	3	1	2	3
001	668	514	696	577	514	999	.	.	.
002	487	705	668	487	623	545	.	.	.
003	514	516	641	.	.	.	.	.	.
004	487	.	545	.	.	.	.	.	.
005	487	674	596	487	514	545	460	460	460
006	705	545	545	516	460	575	460	487	545
007	516	631	862	514	460	577	460	487	545
008	460	516	516	460	460	487	460	514	460
009	487	545	546	460	460	541	460	460	460
010	546	573	609	514	487	659	573	460	516
011	487	546	516	487	487	487	.	.	.
012	487	668	744	460	487	460	460	460	460
013	543	659	641	516	516	487	668	487	666
014	545	541	705	460	460	460	514	460	609
015	545	744	712	487	516	637	460	487	516
016	545	573	862	.	516	698	460	541	545
017	487	514	637	460	516	487	487	487	460
018	516	545	742	516	573	609	487	712	641
019	460	516	487	460	516	696	460	668	705
020	460	609	825	666	487	545	514	460	487
021	605	516	516	545	460	516	460	460	631
022	487	573	668	545	541	631	487	460	487
023	607	487	545	487	541	666	460	460	545
024	487	771	744	487	607	637	460	487	487
025	516	744	750	487	596	487	545	514	487
026	666	577	705	545	541	666	771	514	545
027	516	460	487	631	460	577	575	460	516
028	577	605	607	631	541	605	460	460	460
029	487	575	825	487	545	487	460	487	546
030	516	487	514	487	460	487	460	460	460
031	545	545	545	460	487	666	546	460	541
032	516	659	641	487	516	631	487	516	516
033	460	573	744	514	487	487	514	487	487
034	577	783	823	487	573	541	514	487	516
035	514	666	575	487	487	577	460	487	666
036	.	514	744	460	487	666	516	460	545

Table III - Mean left and right gaze thresholds

GRAND MEAN THRESHOLD
milliseconds

Obs.	Four-Digits			Three-Digits			Two-Digits		
	Method			Method			Method		
	1	2	3	1	2	3	1	2	3
001	620	515	621	561	487	999	.	.	.
002	516	741	654	487	555	543	.	.	.
003	501	578	593	.	.	.	.	.	.
004	573	.	628	.	.	.	.	.	.
005	487	690	650	487	515	559	460	474	474
006	655	530	593	502	474	545	460	474	560
007	488	668	857	529	474	604	460	487	516
008	460	529	502	460	460	502	460	487	460
009	487	584	560	460	460	514	460	460	460
010	545	584	679	514	474	650	574	474	516
011	487	517	502	516	487	487	.	.	.
012	474	645	743	460	474	474	460	474	460
013	610	618	650	502	488	548	671	487	648
014	529	529	657	474	460	488	501	460	534
015	561	710	689	516	488	591	460	487	502
016	516	589	735	.	502	647	474	501	545
017	474	501	562	460	488	474	474	474	474
018	502	502	689	515	584	679	474	643	608
019	460	502	487	460	530	606	474	686	668
020	502	676	825	591	514	561	501	460	541
021	694	530	530	545	474	530	474	474	620
022	502	590	668	502	514	559	487	474	502
023	561	514	594	576	514	666	474	460	545
024	516	757	728	487	576	576	474	487	530
025	502	744	727	474	584	559	516	514	474
026	708	586	708	530	557	653	673	487	530
027	516	488	516	588	460	546	517	460	545
028	609	560	641	631	514	605	460	460	460
029	502	603	742	474	516	532	502	487	530
030	502	502	514	474	460	487	474	460	474
031	561	545	647	518	501	591	546	474	514
032	488	616	674	502	546	648	487	556	556
033	502	559	660	487	501	516	487	474	516
034	586	487	502	487	584	541	529	487	502
035	501	670	621	487	474	577	488	474	576
036	.	544	675	642	487	591	546	460	560

RESULTS

The tabulated results and the interaction plots are shown in the following pages and in the indicated order.

Right direction gaze thresholds. The following results are from analysis performed on the data in Table I.

DIGITS

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	202062.435	101031.217	13.516	.0001
Residual	88	657777.675	7474.746		

Dependent: Four-Digits (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Four-Digits (ms)

Count	91
R	.485
R-Squared	.235
Adjusted R-Squared	.218
RMS Residual	86.457

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	202062.435	101031.217	13.516	.0001
Error	88	657777.675	7474.746		
Total	90	859840.110			

Model Coefficient Table
Dependent: Four-Digits (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		651.806	15.528	41.976	.0001
Methods	method 1	-114.841	22.335	-5.142	.0001
	method 2	-40.742	21.960	-1.855	.0669
	method 3	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	73722.166	36861.083	11.865	.0001
Residual	88	273390.823	3106.714		

Dependent: Three-Digits (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Three-Digits (ms)

Count	91
R	.461
R-Squared	.212
Adjusted R-Squared	.194
RMS Residual	55.738

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	73722.166	36861.083	11.865	.0001
Error	88	2733390.823	3106.714		
Total	90	347112.989			

Model Coefficient Table
Dependent: Three-Digits (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		562.839	10.011	56.223	.0001
Methods	method 1	-58.046	14.399	-4.031	.0001
	method 2	-61.774	14.157	-4.3636	.0001
	method 3	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	29699.516	14849.758	7.520	.0010
Residual	88	173782.594	1974.802		

Dependent: Two-Digits (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Two-Digits (ms)

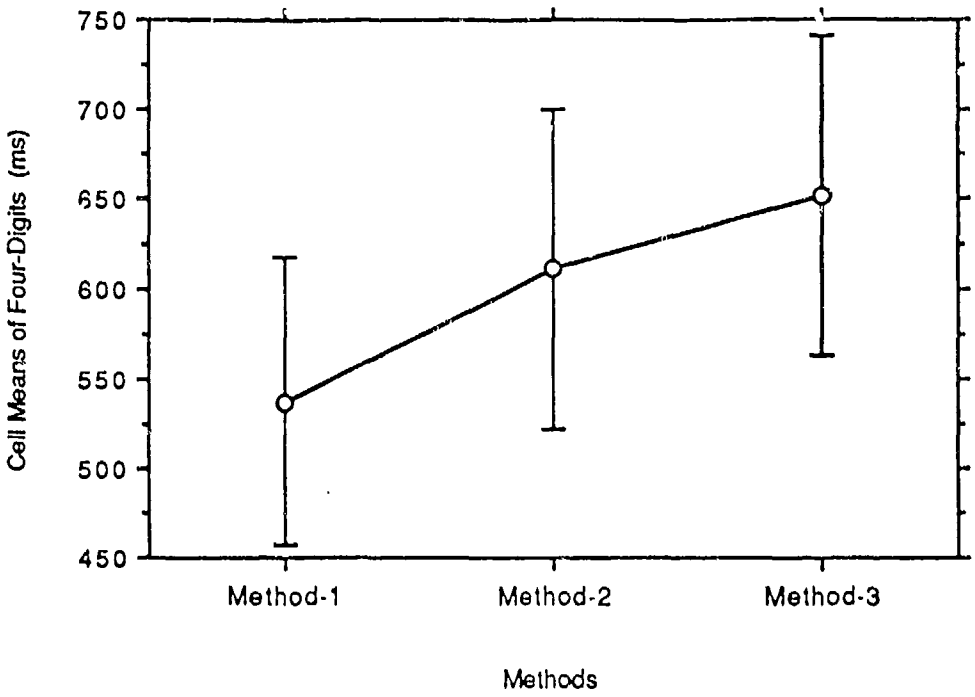
Count	91
R	.382
R-Squared	.146
Adjusted R-Squared	.127
RMS Residual	44.439

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	29699.516	14849.758	7.520	.0010
Error	88	173782.594	1974.302		
Total	90	203482.110			

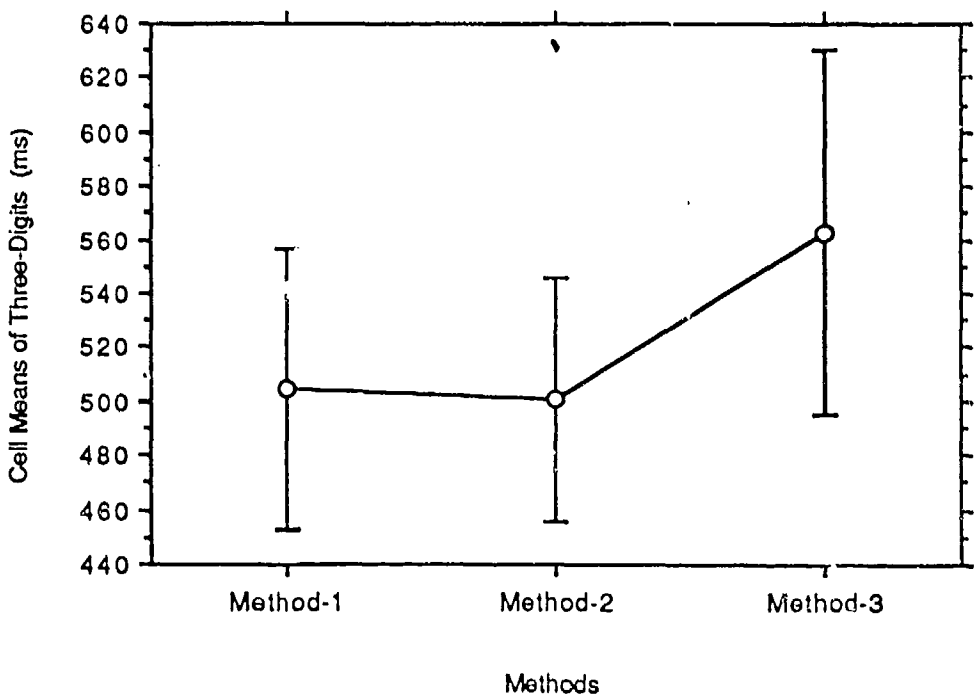
Model Coefficient Table
Dependent: Two-Digits (ms)

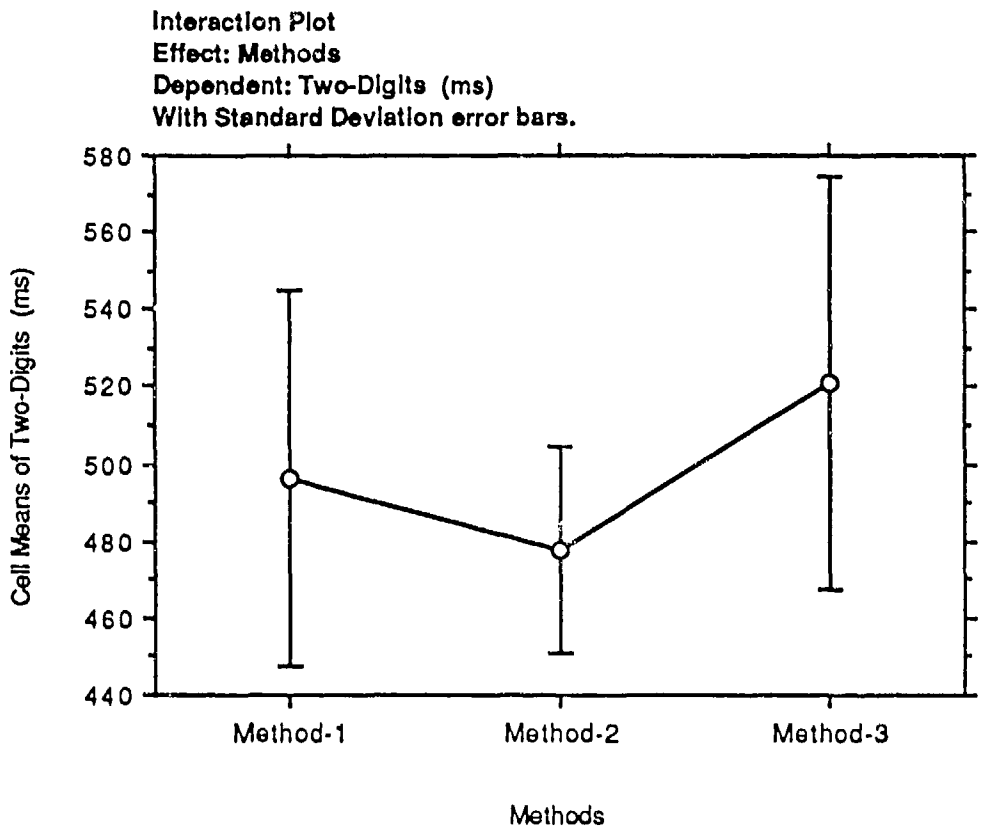
		Beta	Std. Error	t-Test	P-Value
Intercept		521.097	7.981	65.289	.0001
Methods	method 1	-24.786	11.480	-2.159	.0336
	method 2	-43.645	11.287	-3.867	.0002
	method 3	0.000	.	.	.

Interaction Plot
Effect: Methods
Dependent: Four-Digits (ms)
With Standard Deviation error bars.



Interaction Plot
Effect: Methods
Dependent: Three-Digits (ms)
With Standard Deviation error bars.





Type III MANOVA Table
Effect: Methods

S 2
M 0.000
N 42.000

	Value	F-Value	Num DF	Den DF	P-Value
Wilks' Lambda	.602	8.283	6.000	172.000	.0001
Roy's Greatest Root	.400				
Hotelling-Lawley Trace	.587	8.311	6.000	170.000	.0001
Pillai Trace	.443	8.252	6.000	174.000	.0001

METHODS

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	24941.367	12470.683	2.634	.0770
Residual	96	454535.805	4734.748		

Dependent: Method-1 (ms)

NOTE: 9 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Method-1 (ms)

Count	99
R	.228
R-Squared	.052
Adjusted R-Squared	.032
RMS Residual	68.810

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	24941.367	12470.683	2.634	.0770
Error	96	454535.805	4734.748		
Total	98	479477.172			

Model Coefficient Table
Dependent: Method-1 (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		537.429	11.631	46.207	.0001
Digits	two digits	-38.816	16.971	-2.287	.0244
	three digits	-21.035	16.696	-1.260	.2108
	four digits	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	359972.304	179986.152	44.892	.0001
Residual	96	384896.242	4009.336		

Dependent: Method-2 (ms)

NOTE: 9 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Method-2 (ms)

Count	99
R	.695
R-Squared	.483
Adjusted R-Squared	.473
RMS Residual	63.3119

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	359972.304	179986.152	44.892	.0001
Error	96	384896.242	4009.336		
Total	98	744868.545			

Model Coefficient Table
Dependent: Method-2 (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		613.543	10.703	57.325	.0001
Digits	two digits	-136.091	15.617	-8.714	.0004
	three digits	-114.149	15.364	-7.430	.0001
	four digits	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	251747.018	125873.509	17.206	.0001
Residual	96	702291.608	7315.538		

Dependent: Method-3 (ms)

NOTE: 9 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Method-3 (ms)

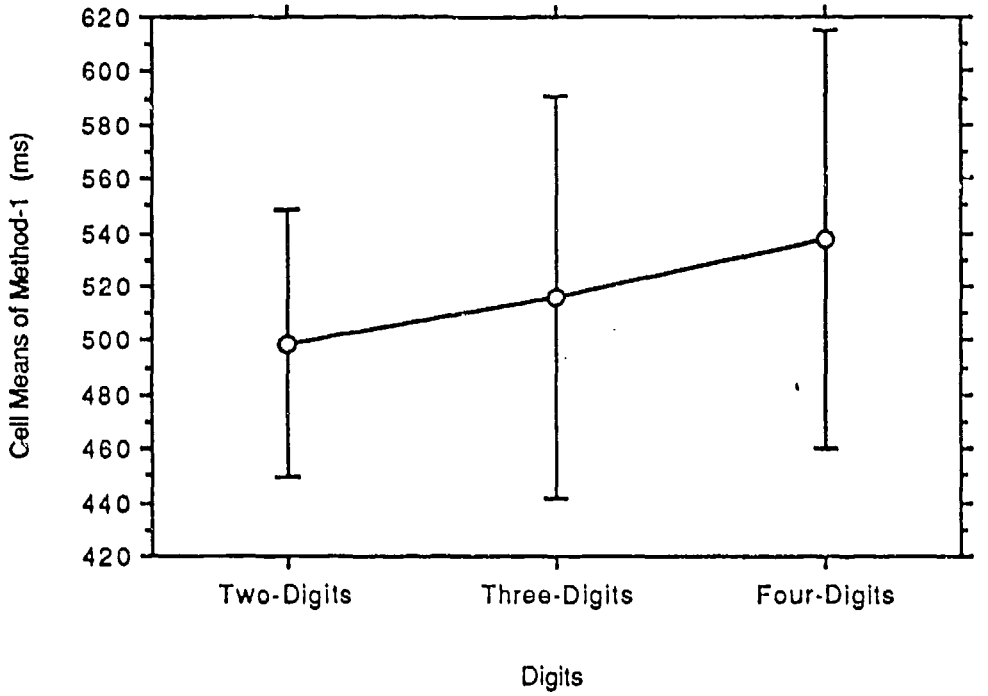
Count	99
R	.514
R-Squared	.264
Adjusted R-Squared	.249
RMS Residual	85.531

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	251747.018	125873.509	17.206	.0001
Error	96	702291.608	7315.538		
Total	980	954.038.626			

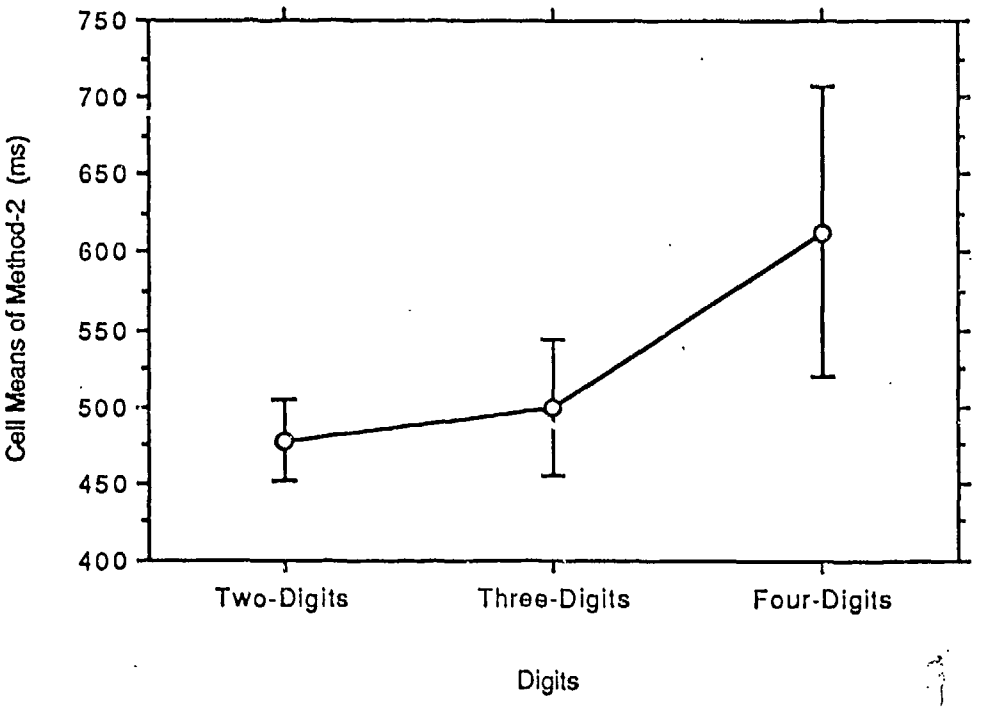
Model Coefficient Table
Dependent: Method-3 (ms)

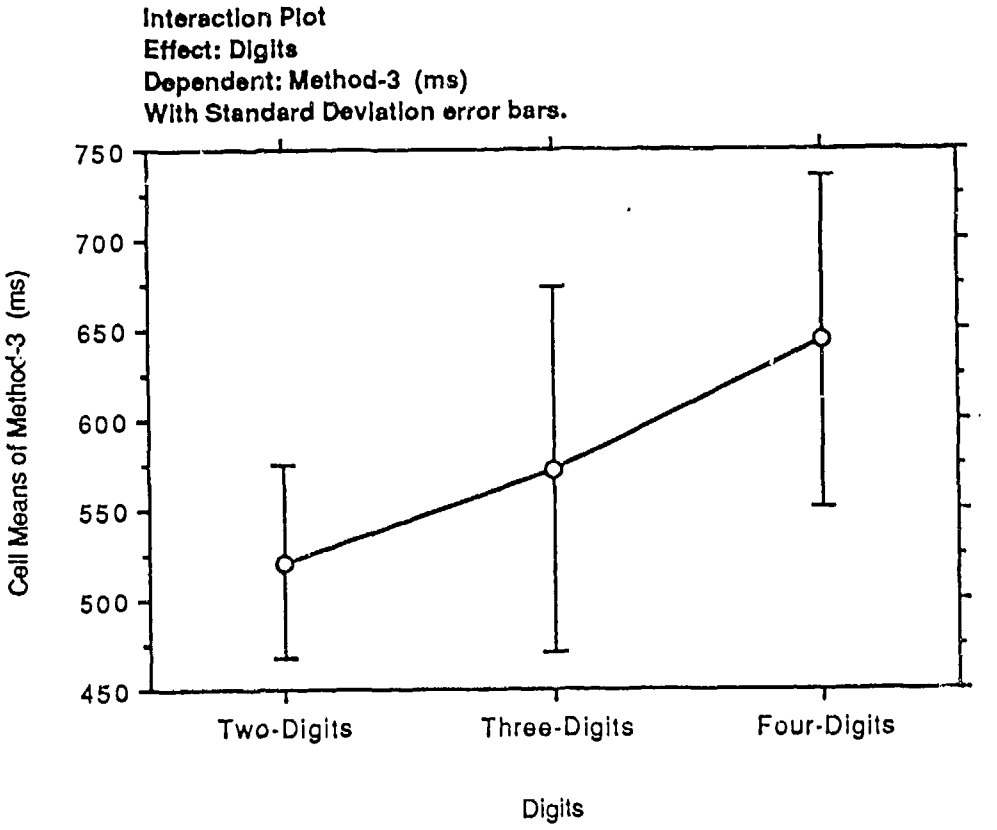
		Beta	Std. Error	t-Test	P-Value
Intercept		643.771	14.457	44.529	.0001
Digits	two digits	-122.675	21.095	-5.815	.0001
	three digits	-71.681	20.753	-3.454	.0008
	four digits	0.000	.	.	.

Interaction Plot
Effect: Digits
Dependent: Method-1 (ms)
With Standard Deviation error bars.



Interaction Plot
Effect: Digits
Dependent: Method-2 (ms)
With Standard Deviation error bars.





Type III MANOVA Table
Effect: Digits

S 2
M 0.000
N 46.000

	Value	F-Value	Num DF	Den DF	P-Value
Wilks' Lambda	.479	13.951	6.000	188.000	.0001
Roy's Greatest Root	1.029				
Hotelling-Lawley Trace	1.058	16.403	6.000	186.000	.0001
Pillai Trace	.536	11.589	6.000	190.000	.0001

Left direction gaze thresholds. The following results are from analysis performed on the data in Table II.

DIGITS

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	260444.274	130222.137	15.658	.0001
Residual	88	731859.858	8316.589		

Dependent: Four-Digits (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Four-Digits (ms)

Count	91
R	.512
R-Squared	.262
Adjusted R-Squared	.246
RMS Residual	91.195

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	260444.274	130222.137	15.658	.0001
Error	88	731859.858	8316.589		
Total	90	992304.132			

Model Coefficient Table
Dependent: Four-Digits (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		660.065	16.379	40.299	.0001
Methods	method 1	-131.789	23.560	-5.594	.0001
	method 2	-66.903	23.164	-2.888	.0049
	method 3	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	87791.741	43895.871	12.541	.0001
Residual	88	308008.699	3500.099		

Dependent: Three-Digits (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Three-Digits (ms)

Count	91
R	.471
R-Squared	.222
Adjusted R-Squared	.204
RMS Residual	59.162

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	87791.741	43895.871	12.541	.0001
Error	88	308008.699	3500.099		
Total	90	395800.440			

Model Coefficient Table
Dependent: Three-Digits (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		573.871	10.626	54.008	.0001
Methods	method 1	-65.492	15.284	-4.285	.0001
	method 2	-65.581	15.027	-4.364	.0001
	method 3	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	26045.233	13022.617	2.994	.0552
Residual	88	382760.525	4349.551		

Dependent: Two-Digits (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Two-Digits (ms)

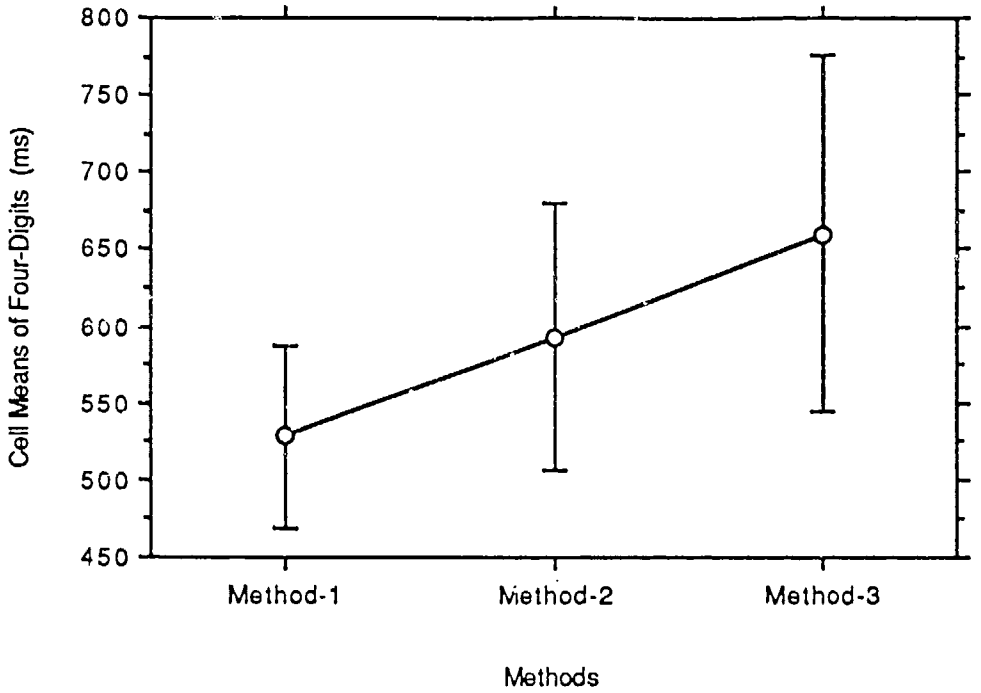
Count	91
R	.252
R-Squared	.064
Adjusted R-Squared	.042
RMS Residual	65.591

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	26045.233	13022.617	2.994	.0552
Error	88	382760.525	4349.551		
Total	90	408805.758			

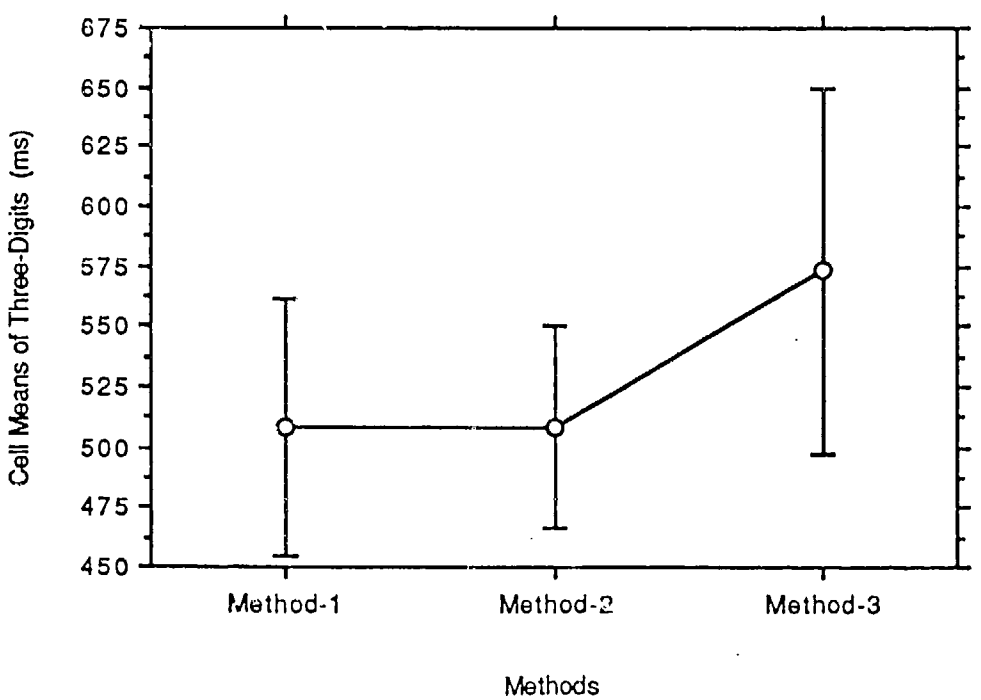
Model Coefficient Table
Dependent: Two-Digits (ms)

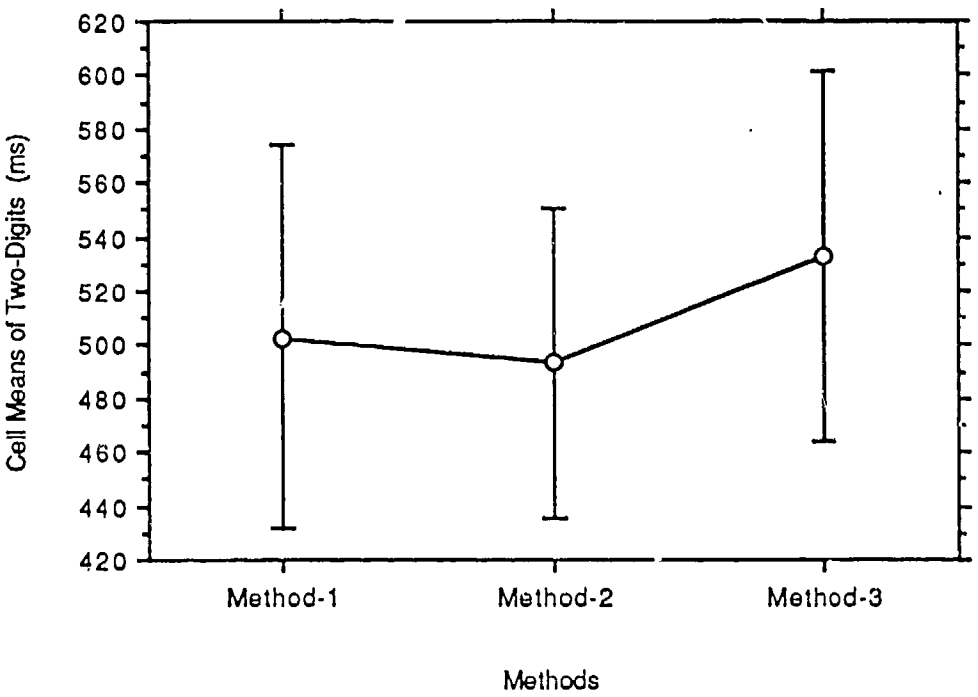
		Beta	Std. Error	t-Test	P-Value
Intercept		532.581	11.845	44.962	.0001
Methods	method 1	-29.753	17.038	-1.746	0843
	method 2	-39.387	16.752	-2.351	.0209
	method 3	0.000	.	.	.

Interaction Plot
Effect: Methods
Dependent: Four-Digits (ms)
With Standard Deviation error bars.



Interaction Plot
Effect: Methods
Dependent: Three-Digits (ms)
With Standard Deviation error bars.





Type III MANOVA Table
Effect: Methods

S 2
M 0.000
N 42.000

	Value	F-Value	Num DF	Den DF	P-Value
Wilks' Lambda	.613	7.941	6.000	172.000	.0001
Roy's Greatest Root	.545				
Hotelling-Lawley Trace	.601	8.508	6.000	170.000	.0001
Pillai Trace	.405	7.371	6.000	174.000	.0001

METHODS

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	14592.055	7296.028	1.950	.1479
Residual	95	355469.424	3741.783		

Dependent: Method-1 (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Method-1 (ms)

Count	98
R	.199
R-Squared	.039
Adjusted R-Squared	.019
RMS Residual	61.170

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	14592.055	7296.028	1.950	.1479
Error	95	355469.424	3741.783		
Total	97	370061.480			

Model Coefficient Table
Dependent: Method-1 (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		530.029	10.491	50.524	.0001
Methods	two digits	-28.158	15.191	-1.854	.0669
	three digits	-22.332	14.948	-1.494	.1385
	four digits	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	186509.326	93254.663	21.503	.0001
Residual	95	412002.276	4336.866		

Dependent: Method-2 (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Method-2 (ms)

Count	98
R	.558
R-Squared	.312
Adjusted R-Squared	.297
RMS Residual	65.855

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	186509.326	93254.663	21.503	.0001
Error	95	412002.276	4336.866		
Total	97	598511.602			

Model Coefficient Table
Dependent: Method-2 (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		592.794	11.294	52.487	.0001
Methods	two digits	-99.601	16.354	-6.090	.0001
	three digits	-81.734	16.093	-5.079	.0001
	four digits	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	245475.882	122737.941	12.823	.0001
Residual	95	909286.526	9571.437		

Dependent: Method-3 (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

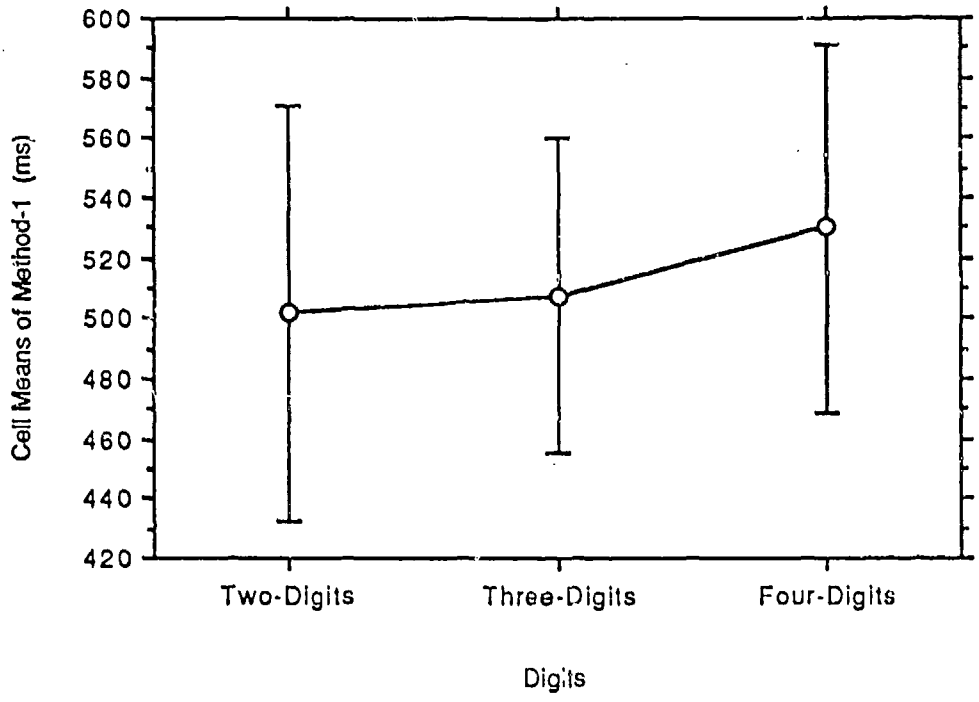
Model Summary
Dependent: Method-3 (ms)

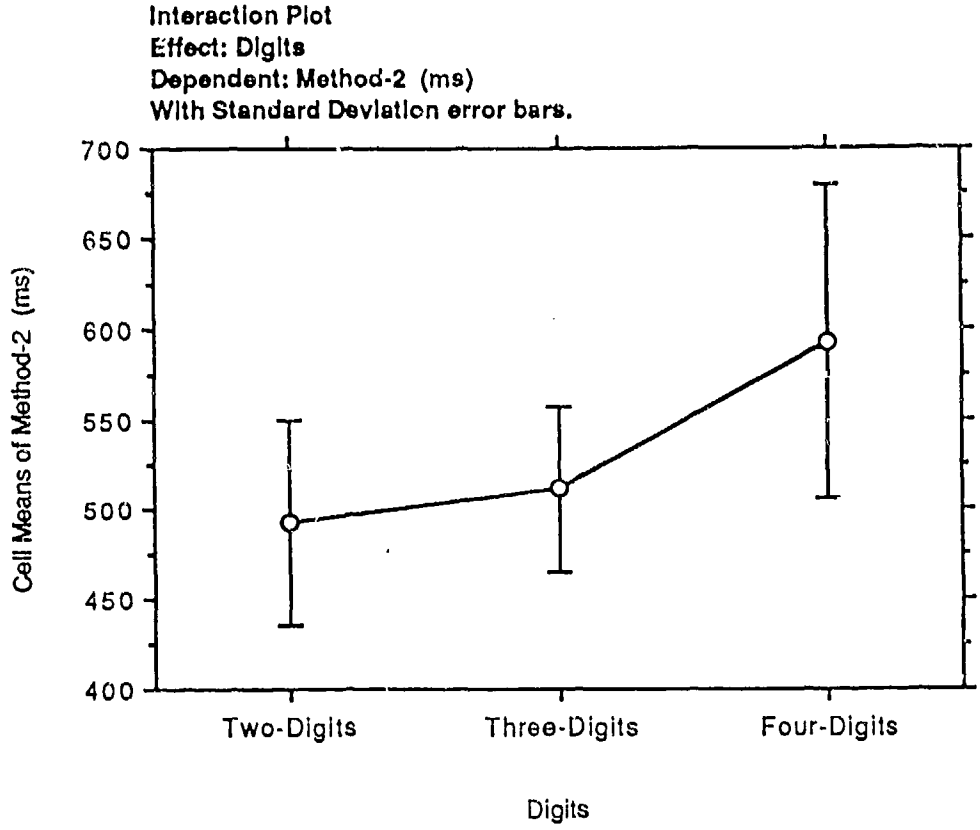
Count	98
R	.461
R-Squared	.213
Adjusted R-Squared	.196
RMS Residual	97.834

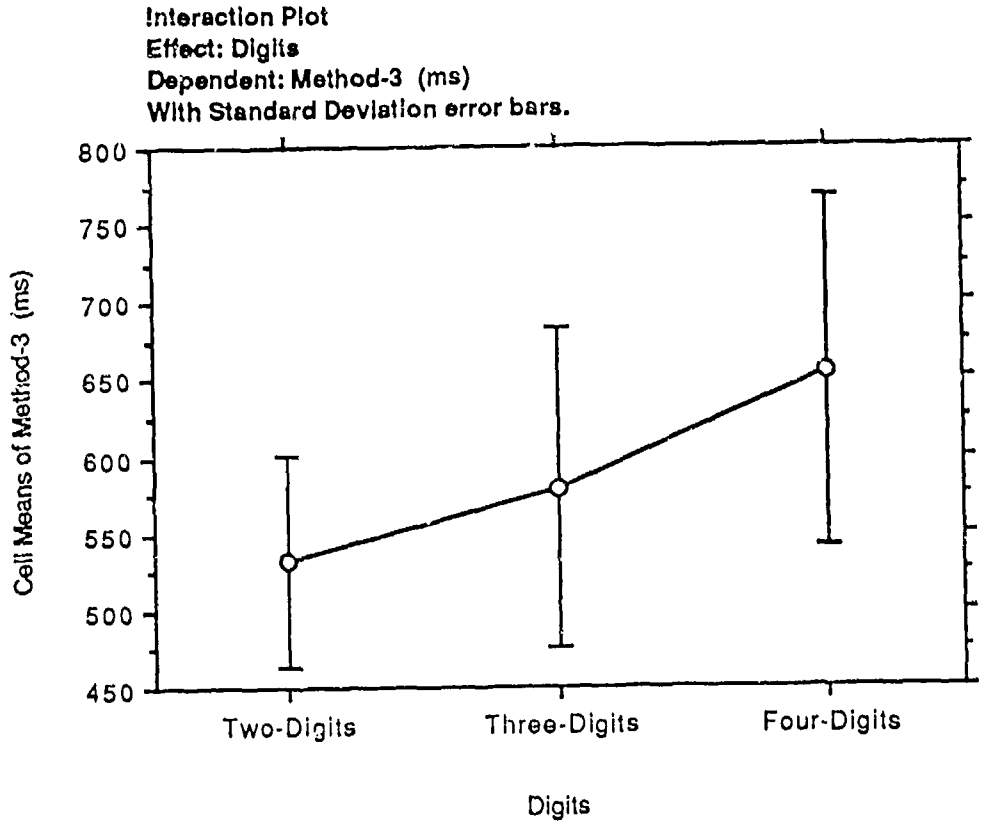
	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	245475.382	122737.941	12.823	.0001
Error	95	909286.526	9571.437		
Total	97	1154762.408			

Model Coefficient Table
Dependent: Method-3 (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		654.088	16.778	38.984	.0001
Methods	two digits	-121.508	24.295	-5.001	.0001
	three digits	-74.603	23.907	-3.121	.0024
	four digits	0.000	.	.	.


Interaction Plot
Effect: Digits
Dependent: Method-1 (ms)
With Standard Deviation error bars.
Cell Means of Method-1 (ms)
600
580
560
540
520
500
480
460
440
420
Two-Digits
Three-Digits
Four-Digits
Digits


Interaction Plot
Effect: Digits
Dependent: Method-2 (ms)
With Standard Deviation error bars.
Cell Means of Method-2 (ms)
700
650
600
550
500
450
400
Two-Digits
Three-Digits
Four-Digits
Digits



Type III MANOVA Table
Effect: Digits

S 2
M 0.000
N 45.500

	Value	F-Value	Num DF	Den DF	P-Value
Wilks' Lambda	.628	8.128	6.000	186.000	.0001
Roy's Greatest Root	.571				
Hotelling-Lawley Trace	.585	8.971	6.000	184.000	.0001
Pillai Trace	.377	7.288	6.000	188.000	.0001

Average left and right direction gaze thresholds. The following results are from analysis performed on the data in Table III.

DIGITS

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	182148.316	91074.158	13.956	.0001
Residual	86	561237.729	6526.020		

Dependent: Four-Digits (ms)

NOTE: 19 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Four-Digits (ms)

Count	89
R	.495
R-Squared	.245
Adjusted R-Squared	.227
RMS Residual	80.784

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	182148.316	91074.158	13.956	.0001
Error	86	561237.729	6526.020		
Total	88	743386.045			

Model Coefficient Table
Dependent: Four-Digits (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		645.000	14.749	43.732	.0001
Methods	method 1	-111.069	21.037	-5.280	.0001
	method 2	-58.067	20.858	-2.784	.0066
	method 3	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	75572.362	37786.181	16.269	.0001
Residual	86	199742.694	2322.589		

Dependent: Three-Digits (ms)

NOTE: 19 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Three-Digits (ms)

Count	89
R	.524
R-Squared	.274
Adjusted R-Squared	.258
RMS Residual	48.193

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	75572.362	37786.181	16.269	.0001
Error	86	199742.294	2322.589		
Total	88	275315.056			

Model Coefficient Table
Dependent: Three-Digits (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		576.6	8.799	64.508	.0001
Methods	method 1	-60.979	12.550	-4.859	.0001
	method 2	-62.267	12.443	-5.004	.0001
	method 3	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Methods	2	21833.685	10916.842	3.772	.0552
Residual	86	2489900.225	2894.189		

Dependert: Two-Digits (ms)

NOTE: 17 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Two-Digits (ms)

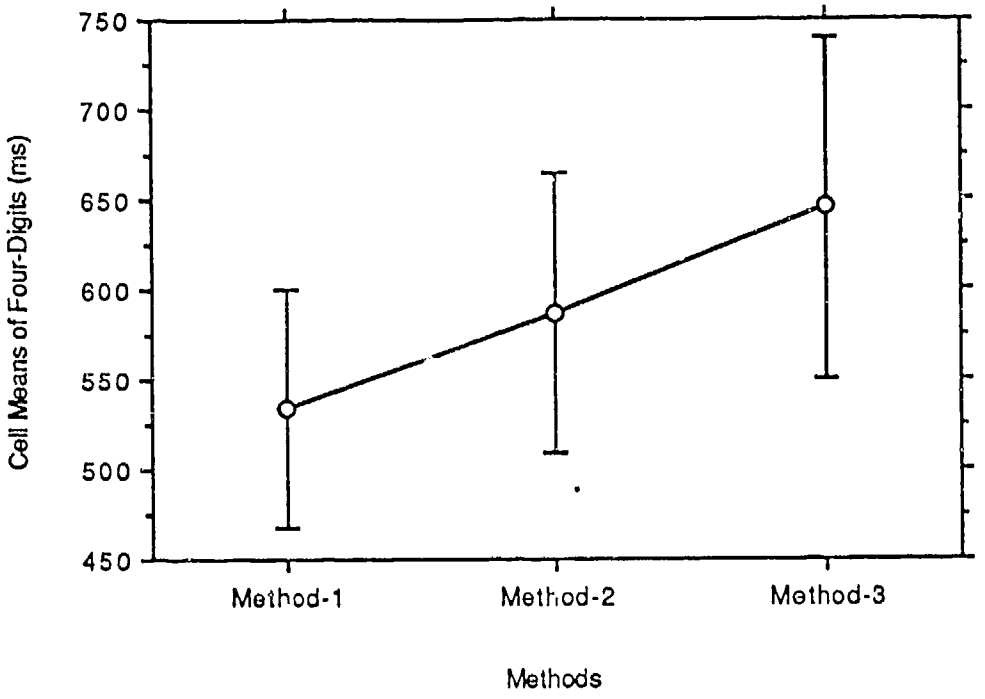
Count	89
R	.284
R-Squared	.081
Adjusted R-Squared	.059
RMS Residual	53.798

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	21833.685	10916.842	3.772	.0269
Error	86	248900.225	2894.189		
Total	88	270733.910			

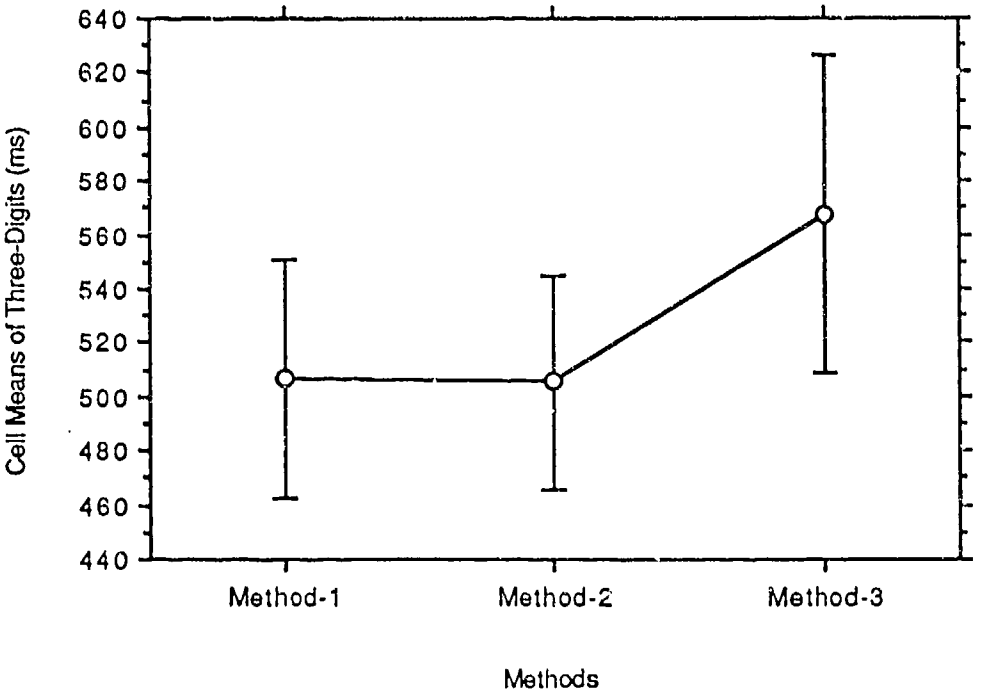
Model Coefficient Table
Dependent: Two-Digits (ms)

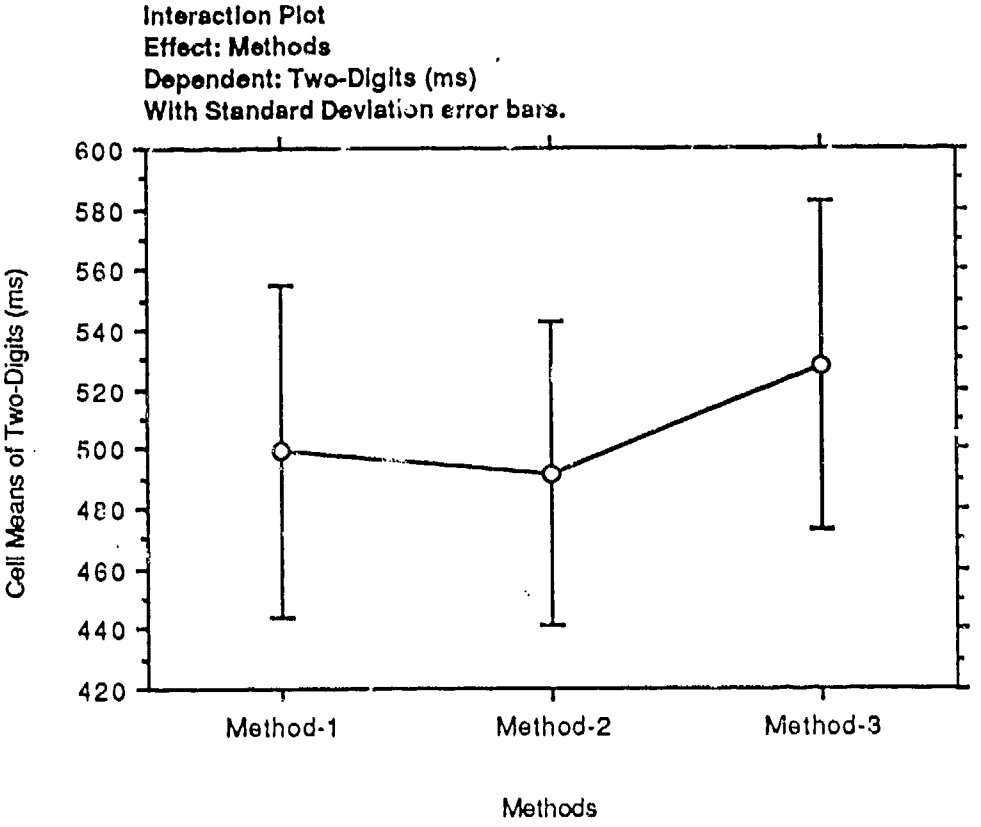
		Beta	Std. Error	t-Test	P-Value
Intercept		528.000	9.822	53.757	.0001
Methods	method 1	-28.793	14.101	-2.055	.0429
	method 2	-36.133	13.890	-2.601	.0109
	method 3	0.000	.	.	.

Interaction Plot
Effect: Methods
Dependent: Four-Digits (ms)
With Standard Deviation error bars.



Interaction Plot
Effect: Methods
Dependent: Three-Digits (ms)
With Standard Deviation error bars.





Type III MANOVA Table
Effect: Methods

S 2
M 0.000
N 41.000

	Value	F-Value	Num DF	Den DF	P-Value
Wilks' Lambda	.617	7.653	6.000	168.000	.0001
Roy's Greatest Root	.516				
Hotelling-Lawley Trace	.585	8.099	6.000	166.000	.0001
Pillai Trace	.405	7.203	6.000	170.000	.0001

METHODS

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	20832.391	10416.195	3.481	.0349
Residual	93	278298.849	2992.461		

Dependent: Method-1 (ms)

NOTE: 12 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Method-1 (ms)

Count	96
R	.264
R-Squared	.070
Adjusted R-Squared	.050
RMS Residual	54.703

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	20832.391	10416.195	3.481	.0349
Error	93	278298.849	2992.461		
Total	95	299131.240			

Model Coefficient Table
Dependent: Method-1 (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		533.059	9.382	56.820	.0001
Methods	two digits	-34.692	13.703	-2.532	.0130
	three digits	-25.059	13.473	-1.860	.0661
	four digits	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	172872.302	86436.151	23.950	.0001
Residual	93	335636.656	3608.996		

Dependent: Method-2 (ms)

NOTE: 12 rows have been excluded from calculations because of missing values

Model Summary
Dependent: Method-2 (ms)

Count	96
R	.583
R-Squared	.340
Adjusted R-Squared	.326
RMS Residual	60.075

	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	172872.302	86436.151	23.950	.0001
Error	93	335636.656	3608.996		
Total	95	508508.958			

2

Model Coefficient Table
Dependent: Method-2 (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		587.029	10.303	56.978	.0001
Methods	two digits	-95.163	15.048	-6.324	.0001
	three digits	-81.186	14.796	-5.487	.0001
	four digits	0.000	.	.	.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Digits	2	198594.142	99297.071	14.082	.0001
Residual	93	655753.816	7051.116		

Dependent: Method-3 (ms)

NOTE: 12 rows have been excluded from calculations because of missing values

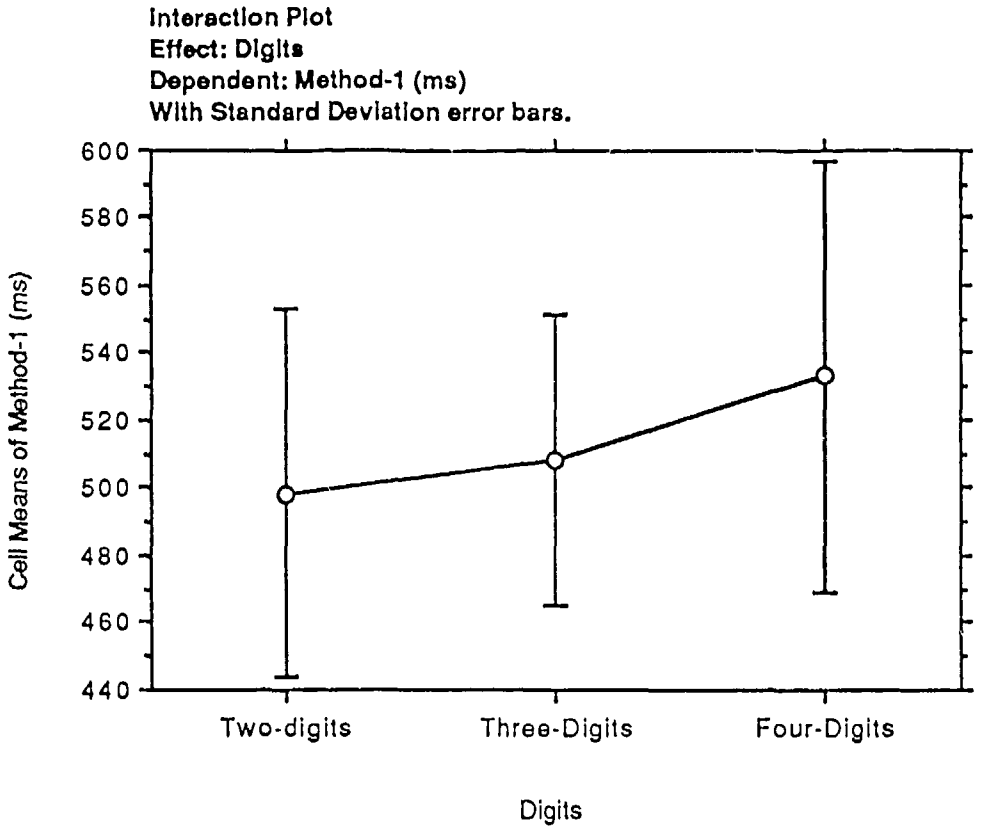
Model Summary
Dependent: Method-3 (ms)

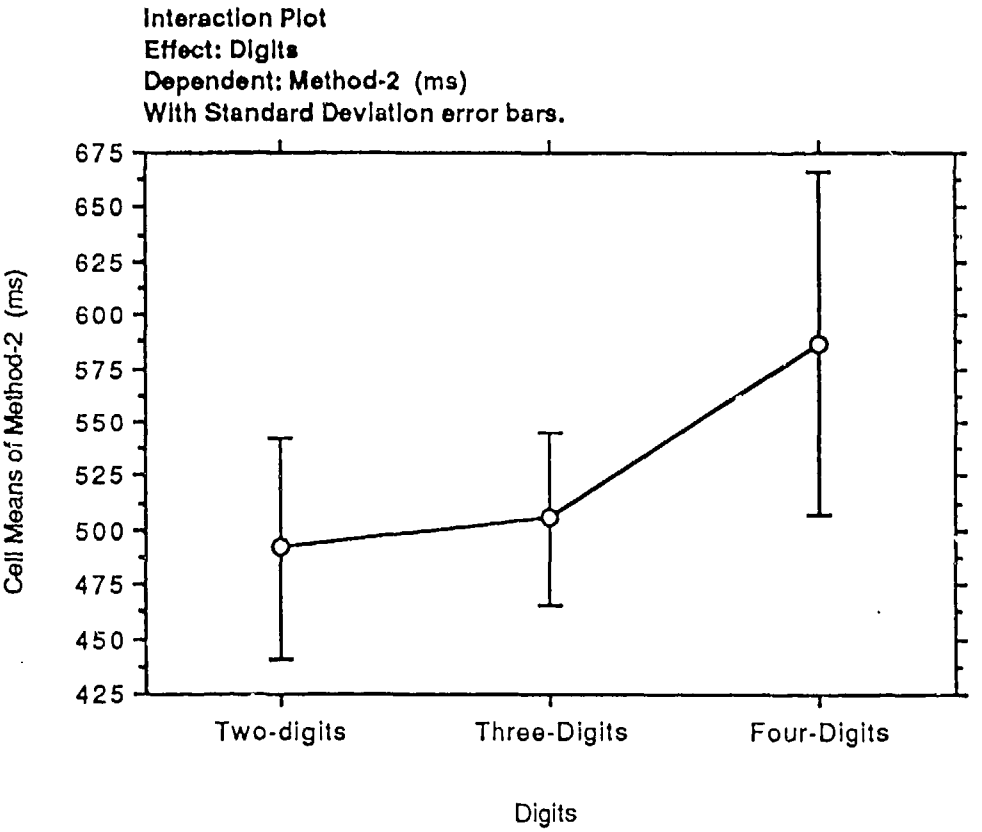
Count	96
R	.482
R-Squared	.232
Adjusted R-Squared	.216
RMS Residual	83.971

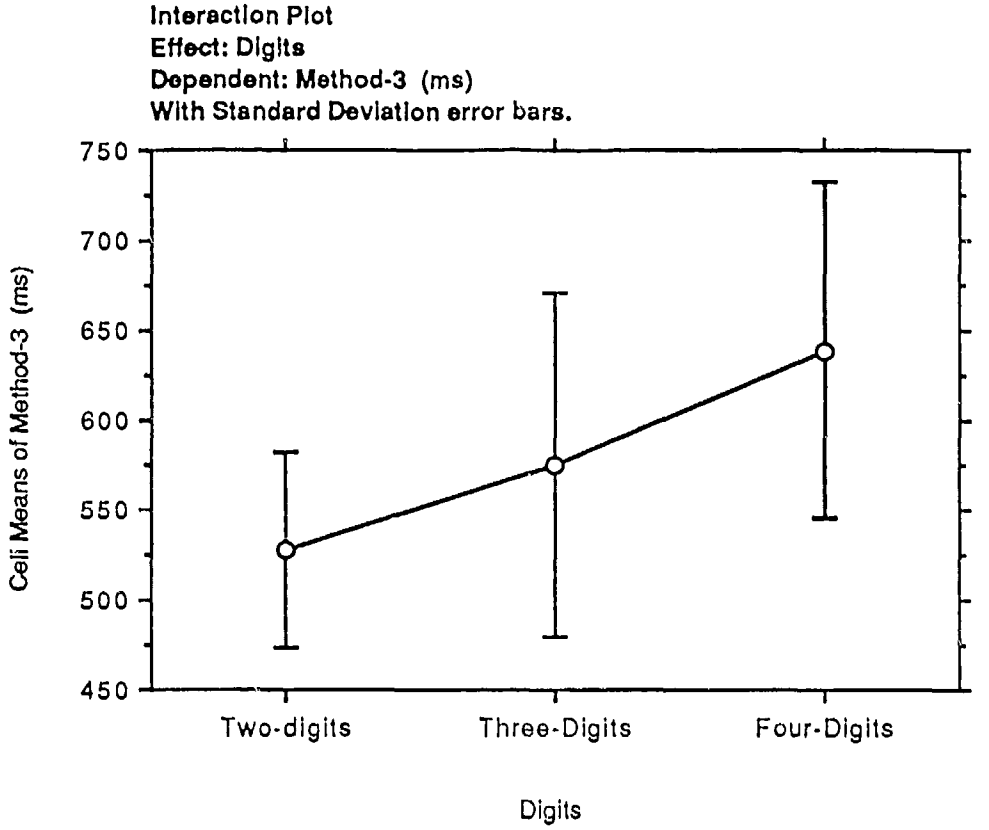
	df	Sum of Squares	Mean Square	F-Value	P-Value
Model	2	198594.142	99297.071	14.082	.0001
Error	93	655753.816	7051.116		
Total	95	854347.958			

Model Coefficient Table
Dependent: Method-3 (ms)

		Beta	Std. Error	t-Test	P-Value
Intercept		638.824	14.401	44.360	.0001
Methods	two digits	-110.824	21.034	-5.269	.0001
	three digits	-63.511	20.682	-3.071	.0028
	three digits	0.000	.	.	.


Interaction Plot
Effect: Digits
Dependent: Method-1 (ms)
With Standard Deviation error bars.
Cell Means of Method-1 (ms)
600
580
560
540
520
500
480
460
440
Two-digits
Three-Digits
Four-Digits
Digits


Interaction Plot
Effect: Digits
Dependent: Method-2 (ms)
With Standard Deviation error bars.
Cell Means of Method-2 (ms)
675
650
625
600
575
550
525
500
475
450
425
Two-digits
Three-Digits
Four-Digits
Digits



Type III MANOVA Table
Effect: Digits

S 2
M 0.000
N 44.500

	Value	F-Value	Num DF	Den DF	P-Value
Wilks' Lambda	.584	9.357	6.000	182.000	.0001
Roy's Greatest Root	.657				
Hotelling-Lawley Trace	.690	10.356	6.000	180.000	.0001
Pillai Trace	.429	8.364	6.000	184.000	.0001

DISCUSSION

Analysis of variance performed on the response data indicates that threshold measurements obtained using Methods-2 and -3 are significantly different. Thus the null hypothesis that administration of the VORPET using the automated voice-recognition system will yield the same threshold measures as those of the manual test administration should be rejected.

Interaction plots of the variable Method-1 for the three analyses show varied effect results as a function of stimuli digits used. For the right-directed gaze, analyses indicate no significant difference as a function of the number of digits used. For the left-directed and the average gazes, analyses indicate a significant effect as a function of digits at the $p = 0.07$ and $p = 0.03$ level. At a $p < .01$, results indicate that there is no significant difference in the means, but it could be because the standard deviation is relatively large. The use of the voice-recognition system should have yielded the same threshold measure of 460 ms regardless of the number of stimuli digits used, when administering the VORPET by Method-1, since the subjects looked directly at the stimuli digits presented on the CRT with no head movement. The interaction plots should have shown a horizontal line (the threshold value) as a function of the number of digits used during administration of the VORPET.

Inspection of the interaction plots and the ANOVA results for the case when Digits is the dependent variable and Methods is the effect or independent variable, the mean threshold for Four-Digits (right, left, or grand mean) is lowest with Method-1, next higher with Method-2, and highest with Method-3, with a significant difference between the means of Method-2 and -3. With Three-digits, the mean threshold is about the same for Method-1 and -2 and substantially higher for Method-3. Using Two-Digits, the mean threshold for Method-2 is lower than that for Method-1 and substantially lower as compared to that of Method-3. In all cases, the means obtained from Method-2 and -3 are significantly different, indicating that the null hypothesis should be rejected.

Comparison of the interaction plots and the ANOVA results for the variables Method-2 and Method-3 indicates an increasing trend in the threshold response as a function of the number of digits used as the stimulus. The increased trend is more linear for variable Method-3 than for Method-2.

4. CONCLUSIONS

The threshold measures for right- and left-directed gaze shifts obtained by Methods-2 and -3 were statistically different. This means that the voice-recognition system as an alternative use to the manual method to automate the administration of the NMPTB tests, is not satisfactory.

In addition, the measures of gaze obtained with method 1 differ significantly with the number of digits (four, three, and two) used.

Full automation of the VORPET cannot be accomplished at this time.

The state-of-the-art technology in voice recognition needs further hardware and software improvement. Higher data acquisition sampling rate and more efficient algorithms are needed in order to provide the accuracy required. The use of IBM and IBM-compatible computers, like the 386 and 486 systems with a much higher rate of instruction execution (33 MHz), in combination with faster Digital Signal Processors (DSP) to acquire, analyze human voice responses (50 MHz), and more efficient algorithms, should make acquisition and analysis of rapid voice responses more accurate.

The other listed milestones were not completed. Further work needs to be done in the area of digital signal processing. There is a need for the use of voice-recognition systems in computer based testing similar to the one needed to incorporate the VORPET as part of the NMPTB.

5. REFERENCES

1. Hixson, W. C., Guedry, F. E., Jr., Lentz, J. M., Further Progress in Development of a Performance-based Test of Gaze Control Capability, NAMRL - 1342, Naval Aerospace Medical Research Laboratory, Pensacola, FL, September 1988.

2. Abacus Concepts, SuperANOVA™. (Abacus Concepts, Inc., Berkeley, CA, 1989).